Editorial: Safety Science - Special Issue on Naturalistic Driving Research

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Introduction

A naturalistic driving study can be defined as "A study undertaken to provide insight into driver behavior during everyday trips by recording details of the driver, the vehicle and the surroundings through unobtrusive data gathering equipment and without experimental control" (Van Schagen et al., 2011). The principle of naturalistic driving studies is close to the common sense reasoning that, in order to understand driving behavior it is important to monitor and observe drivers in their everyday driving activities, under a variety of conditions and for a long period of time. Indeed, experience indicates that participants in naturalistic driving experiments quickly forget the presence of cameras and sensors, which are as inconspicuous as possible, and behave as close to "natural" as possible: thus a "naturalistic driving study" (TRB, 2011).

Naturalistic research on a significant scale was first applied in the U.S. in the 100-Car Naturalistic Driving Study, which produced a data set with approximately 2 million vehicle miles, almost 43,000 hours of data by 241 primary and secondary drivers (NHTSA, 2006). A very extensive naturalistic driving study, involving approximately 2,000 cars and comprising more than 32 million miles of continuous data from over 3,500 drivers across six data collection sites in the United States has been completed in the U.S. (TRB, 2015) within the Strategic Highway Research Program 2 (SHRP2). Canadian and Australian naturalistic driving studies used the same data acquisition systems with SHRP2, but had considerably lower sample sizes. The Australian study involved 352 drivers driving their vehicle for a period of four months, leading to a database of approximately 1.8 million kilometers (Grzebieta et al., 2017), where as the Canadian study comprises approximately 1.8 million kilometers by 149 drivers (https://insight.canada-nds.net/). In Europe some smaller-scale naturalistic driving studies have been performed, such as the project INTERACTION, investigating the use of in-vehicle equipment while driving (Christoph et al., 2013), the EuroFOT project, aiming to evaluate the safety benefit of a range of active safety systems with a naturalistic field operational test (Benmimoun et al., 2011), and others. The first large scale European naturalistic driving study was performed within the project UDRIVE, involving 192 car drivers, 48 truck drivers, and 47 PTW riders over six European countries and producing a dataset of about 400 vehicle-years of data (van Nes et al., this issue).

With most of the papers originated within the activities of the Sixth International Naturalistic Driving Research Symposium, held at The Hague, The Netherlands on 7-9 June 2017, this Special Issue provides a synthesis of high quality research papers with original contributions and interesting results based on naturalistic driving research. Included papers shed light on methodological aspects of naturalistic driving experiments and provide insight on the results of naturalistic driving research on several aspects of driver behavior, on distraction, on road safety, on the investigation of crashes or near-crash events, and on vulnerable road users (pedestrians, cyclists, older and younger drivers).

Methodological aspects

The design and implementation of a naturalistic driving experiment requires considerable time and effort, and the methodological approach is of critical importance in order to develop a database that will provide extensive, reliable insights into driving behavior in real traffic situations. Some papers in this issue provide valuable insights on the experiment design and the resulting naturalistic driving datasets: In Antin et al. (this issue) the methods used to design the Strategic

Highway Research Program 2 (SHRP2) large-scale naturalistic driving study are presented, along with a highlights of the collected data. The overall management of the study and the encountered challenges are discussed and the strengths and weakness of the study are identified, concluding that the SHRP 2 NDS database continues to be a rich resource for studying real-world driver behavior and driver performance with the aim of making driving safer and more efficient.

Van Nes et al. (this issue) present the European UDRIVE study. Study design and key methodological choices are explained and UDRIVE data characteristics are discussed. A comparison with SHRP2 results indicates interesting differences in the behavior of European drivers with regard to distracting activities, both between European countries and in comparison to the US, thus highlighting the value of UDRIVE dataset for targeted road safety measures in the EU. Also, based on the comparison between different studies, van Nes et al. introduce a conceptual framework for naturalistic driving studies and discuss how the scope of the study can influence sample selection and data acquisition systems.

Ghasemzadeh et al. (this issue) focus on methodologies to extract trips that occur during adverse weather conditions by leveraging data from the SHRP2 Naturalistic Driving Study (NDS) database and the Roadway Information Database (RID), a complementary database with geospatial data (traffic, roadway geometry, accident reports, weather conditions) for commonly driven roads. Three different methodologies are developed and discussed, potentially supporting innovative operational strategies to improve the safety and mobility of the transportation network during adverse weather conditions.

Barbier et al. (this issue) link NDS and video self-confrontation methods, which are based on the display of video sequences of usual driving activities to the driver to spell out subjective experience. Exploiting the UDRIVE dataset and using qualitative indicators derived from the interviews, the researchers concluded that the efficiency of the re-enactment depends on the emotional content; i.e. long-term autoconfrontation is efficient for safety critical situations.

Driver behavior

Driver behavior and human factors research are the fields of research that can exploit the strengths of naturalistic driving approach at a maximum level. Compared to the more traditional driving simulator approach, naturalistic driving studies allow researchers to investigate and analyze the interrelationships between the driver, the vehicle, the road, and other road users in a real environment and in many different circumstances, from ordinary driving to conflict situations and even actual crashes.

Naturalistic driving tests on two-lane mountainous roads were conducted by Deng et al. (this issue) in an attempt to correlate the alignment slope to the physiological signals of drivers (electrocardiographic signals and accelerator/ brake pedal forces), which are linked to driver workload. Ding et al. (this issue) examined the impact of transverse line markings installed on the slow lane of a freeway in China in the car-following headway, using a naturalistic driving approach, and provided evidence that the direct visual intervention on headway (distance) control is basically feasible.

Farah et al. (this issue) focus on driver behavior in horizontal ramp curves in interchanges in the Netherlands, using a hovering helicopter to collect detailed trajectory data of free-moving vehicles on 29 different curves from 6 different interchanges. Speed profiles were found to be significantly affected by the distance along the connection, the design characteristics of the connection, vehicle type, and drivers' heterogeneity.

Zhang & Gao (this issue) applied a naturalistic driving behavior test involving vehicles equipped with eye tracking equipment, in order to study the eye fixation behavior of drivers on expressways in a foggy environment. They found that, when in low visibility environment, drivers tend to focus their attention in the nearby area and have a more focused visual search range.

Fleming et al. (this issue) collected naturalistic data in a small scale study to evaluate existing driver models, with implications for the design of Advanced Driver-Assistance Systems (ADAS). Car following and cornering behavior models were compared against real world naturalistic data, and a small set of parameters were identified that are considered sufficient to characterize driver behavior, and can be estimated in real-time by an ADAS to adapt to changing driver behavior.

A useful source of naturalistic driving data for the study of driver behavior, avoiding expensive in-vehicle devices, are smartphones with their embedded sensors. Mantouka et al. (this issue) used data from smartphones to detect unsafe driving styles, based on information on harsh events occurrence, acceleration profile, mobile usage and speeding. Results indicated that drivers do not maintain a steady driving profile, but instead they change the way they drive on every trip. Papadimitriou et al. (this issue) explored driving behavior during mobile phone use also based on data collected by smartphone sensors. Exposure metrics found to be significantly associated with the probability of mobile phone use were trip length, and driving off-morning rush. Speeding and harsh cornering were found to be negatively associated with the probability of mobile phone use, which is in line with risk compensation theory in human factors research.

Distraction

Distraction is considered a leading driver related factor in fatal crashes and occurs when the attention of drivers is diverted away from the driving task towards competing activities. Dingus et al. (this issue) exploited the SHRP2 NDS database to assess crash risk associated with drivers' engagement in primarily cognitive secondary activities, such as talking/singing, interacting with a passenger, talking/listening on a mobile phone, either handheld or with a hands-free device, and dialing a mobile phone using voice-activated software. Results indicated that such tasks are associated with a significantly increased odds ratio relative to model driving (i.e., drivers are apparently alert, attentive, and sober).

Bakhit et al. (this issue) also used the SHRP2 NDS database to analyze how drivers allocate their attention while driving and provide insights on the relationship between drivers' visual behavior and engagement in different types of secondary activities while driving. Attempting to quantify risk associated with distraction, the authors suggested two indicators: the number of renewal cycles per event (NRC) and the distraction level index (DI), both of which were found to be considerably increased for crash or near crash events.

Off road glances of drivers were also analyzed by Kuo et al. (this issue), in a naturalistic driving study of shift-workers commuting to and from work in Australia. The authors classified off-road glances into glances to the driver lap and center console regions of the vehicle and analyzed them in the context of visual time-sharing sequences, finding that drivers were significantly more likely to look toward their lap when drowsy.

Assessing traffic safety

Naturalistic driving studies are also a valuable research methodology for assessing traffic safety and risk. Raju et al. (this issue) proposed a novel approach for the modelling the probability of rear-end crashes as a function of instant perception time (IPT), measured in a naturalistic driving study in Indian expressways, under heterogeneous traffic environment.

Wang et al. (this issue) focused their attention on the lane change behavior of coaches and developed a lane change safety model using collected naturalistic data from the G30 highway in China. They reported that the higher the coach velocity, the lower the lateral deviation. Also, a more stable lane change behavior for coaches was observed compared to passenger cars, attributed to both the increased experience of coach drivers and the more cautious lane change due to the larger size and passenger capacity.

Towards a more practical application of naturalistic driving research results, Alonso et al. (this issue) proposed a methodology for objectively monitoring the safety level during driving, based on the estimated safety margin under different operating conditions and considering the dynamics of the vehicle and the variables that affect the handling limits and rollover risk of the vehicle.

Investigation and modelling of crashes and near-crash events

Investigating crash progression through naturalistic driving studies can provide a better understanding of the events before and during a crash and thus can contribute to crash prevention. Both related studies included in this special issue have used data from the Second Strategic Highway Research Program (SHRP2) - Naturalist Driving Study. Ali et al. (this issue) used a time-chunking technique to monitor changes in vehicle kinematics on a timescale, and examined parametric and non-parametric techniques to estimate near-crashes on freeways. The models may potentially be useful in the future development of real-time crash prediction systems, e.g. with vehicle kinematic data from Connected Vehicles (CV).

Papazikou et al. (this issue) explored the whole sequence of vehicle kinematics, from normal driving to a crash or near-crash event, in order to identify early crash risk indicators and the factors affecting Time To Collision (TTC). Results indicated that longitudinal acceleration, lateral acceleration and yaw rate can be reliable indicators for detecting deviations from normal driving, and TTC values are affected by vehicle type, speed, longitudinal acceleration and time within the crash sequence.

Vulnerable road users

All kinds of vulnerable road users (pedestrians, cyclists, powered two-wheelers, older and younger drivers) have justifiably gained particular attention in road safety research. Several naturalistic driving studies in this special issue deal with vulnerable users and introduce novel approaches in understanding how they behave in traffic and interact with other road users, and how other road users behave in relation to vulnerable ones. Winkelbauer et al. (this issue) used the UDRIVE database to investigate vehicle headways behind various vehicle types, with emphasis on the time-headway behind powered two-wheelers. Results indicated that the hypotheses of car drivers keeping less time headway behind powered two-wheelers is not supported.

Naturalistic studies of pedestrian behavior in India (Chaudhari et al., this issue; Chaudhari et al., this issue) provide valuable insights of the effect of surrounding factors and individual characteristics on crossing behavior at urban mid-block crosswalks, and model the pedestrian safety margin with regards to the availability of gap in vehicular flow, vehicle type, vehicle yielding behavior and speed of the approaching vehicle.

The behavior of drivers overtaking cyclists sharing the same lane is investigated by Kovaceva et al. (this issue). The study quantified drivers' comfort zone boundaries (CZBs) and investigated the factors that affect them in a naturalistic setting. Results indicated that CZBs increase as the car speed increases and significantly decrease in the presence of an oncoming vehicle.

Naturalistic cycling observational data (GPS and video footage) of cyclists in Melbourne, Australia were used by Lawrence & Oxley (this issue) to understand the factors affecting route choices by cyclists. Findings indicated that most cyclists travelled on a limited number of familiar routes and that safety and the environment were important factors. Route variations within the same origin - destination pair were identified, and subtle real-time traffic and operational conditions were factors that may influence route choice.

Ehsani et al. (this issue) focused on supervised practice driving of young learner drivers in a naturalistic driving context, identifying factors affecting the amount and variety of practice driving. They found that having driven before the learner permit and a good parent-teen relationship was associated with more driving, while higher household income with less driving. Having driven before was also associated to more driving in wet weather.

Finally, Charlton et al. (this issue) investigated changes in driving patterns of older Australian drivers over a five-year period using various functional and health assessments and self-reported driving questionnaires combined with data from in-vehicle data loggers, installed in participants' own vehicles. Reductions in the annual distance driven were found to be significantly associated with being female, increasing age, health reasons and lower night-time driving comfort scores. Reductions in annual trip frequency were associated with increasing age and health reasons. Results suggested that older drivers self-regulate their driving habits, possibly adapting to the gradual deterioration in health and functional status.

Conclusions

In summary, the collection of papers included in this Special Issue represents a snapshot of current naturalistic driving research achievements and addresses a large variety of methodological and practical aspects involved in such studies. Overall, naturalistic driving experiments are usually cumbersome and highly demanding in terms of cost and resources. Very large amounts of data are produced, requiring appropriate data management schemes and high computational capacity.

On the other hand, naturalistic driving experiments are able to overcome many limitations of traditional methods and provide new scientific insights based on data from both inside and outside the vehicle in many different circumstances, from ordinary driving to conflict situations and even actual crashes. This type of data allows researchers to better understand and investigate driver and traffic behavior in many different situations.

Clearly there is much more work to be undertaken in this promising field and many challenges to be addressed. Several different techniques have been used and there is a need to compare and integrate them in order to optimize the reliability and level of detail of research results. The advent of new technologies (e.g. in sensors) gradually simplifies the implementation of naturalistic driving experiments, and new analysis techniques, such as artificial intelligence and machine learning, allow for a more effective and in depth analysis of results. Finally, the consideration of vulnerable road users in naturalistic driving research allows for the identification and understanding of problems specific to these road user groups and the identification of potential solutions in ways not possible so far.

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